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LESSONS LEARNED FROM JOINT TRAINING LAND MANAGMENT

CONTRACT REPORT

by

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1. INTRODUCTION

Knowledge of the manner in which US Foreign Allies manage their lands relative to regulations and compliance requirements can aid in innovative solutions being applied to US Military installation land management practices. Research is required to identify regulatory policies, requirements, and legislation having influence or direct control over installation land management. Research and direct correspondence and on-the-ground data collection is required in order to connect with Foreign Allied military installations in order to understand how users implement and manage the balance in installation land care between compliance requirements and military training mission needs. Through an understanding of the surrounding issues as well as user strategies, guidance and recommendations can be made to aid development of best management practices on US Military installations.

This project will develop a Technical Report documenting how the land managers of Military Installations of Foreign Allied Nations of the United States have dealt with challenges related to the intensified human development, encroachment, soil conservation, climate change, and ecosystem management. This will yield insight into effective and efficient land management practices.

The project will collect data from multiple foreign allied nations of the United States, specifically the United Kingdom and up to five (5) subsequently identified European countries, on the following:

- Relevant regulations and requirements in each respective country pertaining to the land management, land care, and rehabilitation practices on their military installations.
- On-the-ground installation management policies and practices for land management relative to training and natural resource and infrastructure (including natural resource issues and challenges related to climate change, intensified human development, encroachment, soils conservation and ecosystem management).

By researching and learning about innovative technologies and solutions have been developed in other countries in response to more stringent regulations, this project will allow applicable foreign solutions to be identified for use within the US Army. This insight will inform future practices, adaptation and decision management processes for maximum impact for the creation of a sustainable and secure defence future.

In order to support the project outlined above Cranfield University has extensive experience in land degradation and restoration, particularly with respect to the use of the microbial communities to assess ecosystem health and recovery. In addition, Cranfield University has expertise in environmental best-practice of military range management and specific understanding of the fate and transport of energetic materials in soil environments. Due to an excellent understanding of soil environments, environmental management and good understanding of the workings of military ranges Cranfield University has strong links with the UK MoD and

European and International Defence Agencies. Therefore, through these relationships Cranfield University has assisted with the researchers of the ERDC-CERL project team to gain access to restricted sites for observations and field studies.

Cranfield University has assisted with access to some UK and European military installations so that observations and field studies can be carried out to support the above objectives. This has enabled the ERDC-CERL research team to undertake a comparative analysis with these practices and the U.S. Results will be developed into a technical report format, summarizing findings based on collaborative analysis by Cranfield and ERDC-CERL.

1.1 Assistance from Cranfield University

The following is an outline of the overall tasks that were undertaken by Cranfield University to assist ERDC-CERL:

- a) Identified, contacted and arranged for access to Salisbury Plain and Otterburn training areas as they have similar mission requirements and land areas to CONUS Army Installations;
- b) Provided information on regulatory requirements in the UK;
- c) Accompanied ERDC-CERL research team to the UK Military training areas;
- d) Provided information on the UK sites visited, including their capabilities and details associated with UK MoD and International collaboration associated with best management of military training installations;
- e) Prepared a summary report of the visit made by ERDC-CERL to the UK, which includes backgrounds to the military training areas;
- f) Undertake draft review of the Technical Report by ERDC-CERL;
- g) Assist with preparing relevant articles for marketing;
- h) Assist with preparing technical presentation.

1.2 Report Structure

This report is based on requirement 'E' of section 1.1, a visit report. Sections A, B, C and D have been completed and F, G and H are future tasks.

The structure of this report focusses on background to all sites visited, including Cranfield campuses main site, Bedfordshire and Shrivenham, Salisbury Plain and Otterburn Training Areas. It also summarises Cranfield Universities collaboration and research commitments to the UK MoD and knowledge share partnerships with specific NATO panel groups.

2. CRANFIELD UNIVERSITY (MAIN SITE, BEDFORDSHIRE)

2.1 Location of Site and Capabilities

Cranfield campus in Bedfordshire includes an airport in extensive grounds with plenty of free car parking, excellent housing provision and superb sports and recreation facilities. Here you will find the School of Engineering, Cranfield School of Management, Cranfield Health and the School of Applied Sciences, all offering entry at graduate level only. As a result the atmosphere is mature and focused, with an established infrastructure which makes study and leisure time productive and enjoyable.

The campus lies about 10 minutes from the M1 motorway, the UK's main north/south artery, and has rail and road access to most major airports. Situated mid-way between Oxford and Cambridge, it is close to thriving Milton Keynes, a new town with one of the largest covered shopping centres in Europe, and the historic riverside town of Bedford. Both have coach and train stations.

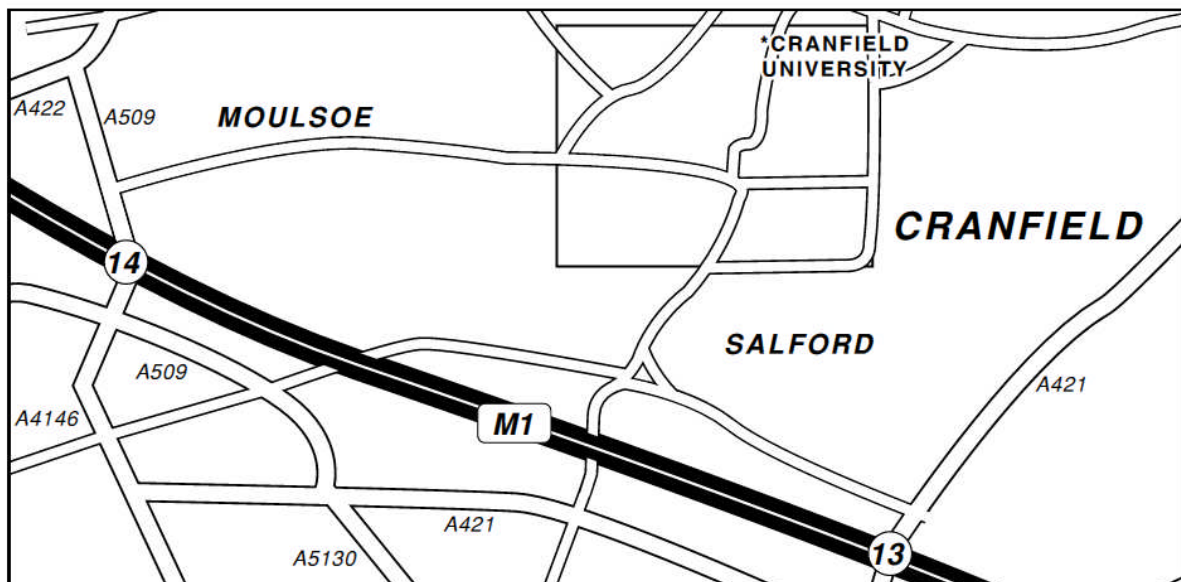


Figure 1 Cranfield Campus in Relation to the M1 Motorway

Cranfield University is a business-focused, postgraduate University with a world class reputation for applied science, technology and management, coupled to fundamental research. Its research, training and consultancy is industrially, or Government funded and, as such, directly informs innovation strategy and policy development. It aims to be exemplary partners for securing deep impact among the end users of Research Council funded science and at the forefront of knowledge exchange. Staff at Cranfield work in multidiscipline, sector-focused groups addressing the following core business sectors:

- Aerospace
- Automotive
- Energy
- Environment
- Healthcare
- Manufacturing

- Security and Defence

The University delivers its business to these core sectors through its five 'Schools'.

The School of Applied Sciences, based at Cranfield close to Milton Keynes, has a turnover of £35m and core expertise in environmental science and technology, manufacturing and materials. It undertakes research and consultancy across the process and supply chains of the main industrial sectors and is a major contributor to the data and evidence supporting environmental policy development in Defra.

Cranfield's aim is to transform all its knowledge to practical application. This is mainly achieved through the work of its students and through its work for sponsoring clients. In order to achieve its aim and deliver its mission, the University has a number of wholly-owned subsidiary companies that provide flexibility and return on investment to the university. Cranfield has two basic criteria for performance which are interdependent – academic excellence and financial viability. Financial health is essential to support the academic work of the University.

2.2 Environmental Sciences at Cranfield

The Department of Environmental Science and Technology in the School of Applied Sciences is the focus of its environment portfolio (www.cranfield.ac.uk/html). Comprising 140 staff and 40+ academics within Institutes of Water Science, Energy and Resource Technology, Risk and Futures, Soil Resources and Automotive Technology, and hold a substantive Research Council portfolio. It has strategic partnerships with Yorkshire Water, Severn Trent Water and Defra. This research and consultancy extends to UK and international clients, including the Research Councils, Defra, DECC, Environment Agency, Natural England, the international water utility sector, the National Science Foundation, the US Water Research Foundation, the Australian Research Council and non-government organisations including the Gates Foundation.

Cranfield has internationally recognised strengths in soil and water management with a profile of international scholarship in these areas. PhD and EngD graduates from the university can be found in leadership positions in the environmental sector in government, industry and academia, with substantial funding from UK Research Councils. Strategic grants include strategic risk and environmental futures (Defra and others including LWEC). It has deep and extensive experience of working with Government (Defra and DECC), the utility sectors and their technology supply chains on issues as diverse as carbon capture and storage, bioaerosol release and the valuation of cultural environmental assets. Expertise straddles the interface between the natural environment and the infrastructures that rely on its resources, goods and services. Amongst strategic environmental areas the university delivers the following:

- Climate system – e.g. water security, climate change adaptation and mitigation, greenhouse gas inventory for agriculture;
- Natural environment-technology interface – carbon capture, bioaerosols, resource recovery and efficiency;
- Biodiversity – soils, urban ecosystems, ecological restoration, modeling;
- Sustainable use of natural resources – mine closure, remote sensing, soil and water management, agriculture, forestry, bio-energy, ecosystem services;

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- Earth system science – biogeochemistry, carbon and nutrient cycling;
- Natural hazards – volcanic dust, floods, soil erosion and landslides;
- Environment, pollution and human health – soil pollution, biomagnification pathways, waste, environmental exposure and human health impacts;
- Technologies – remote sensing, novel sensors, geospatial analysis.

2.3 Summary of a visit by Drs Anne Dain-Owens and Heidi Howard to Cranfield University (main campus), Cranfield, Bedfordshire MK43 0AL, United Kingdom. 12th – 13th September, 2012

Schedule

Time	Activity
<i>12th Sept 2012</i>	
9.00	Arrive & welcome
9.30 – 10.15	Tour of B54 Soil and Water Management and Engineering Facility – The Hudson Building (with Ceri Dawson)
10.15 – 10.45	Tour of Soil and Water Labs (with Richard Andrews)
10.45 – 11.00	Tour of the National Soil Inventory and Soils Archive (with Richard Andrews)
11.00 – 11.20	Tour of Wolfson Field Laboratory and Lysimeters (with Matthew Downie)
11.20 – 12.00	Meet with Dr. Jack Hannam (Senior Research Fellow in Pedology) – Jack's office in B53
12.00	Lunch
12.45	Set up for Doctoral Training Centre Seminar (B42 lecture room)
13.00 – 14.00	Seminar + Discussions on "US Military Research & Development to Support Training Land Management"
14.00 – 14.15	Drink / Comfort Break
14.15 – 14.45	Meet with Dr Rob Simmons (Senior Lecturer in Soil Erosion and Conservation) – Rob's office B53
14.45 – 15.15	Meet with Mr Tim Brewer (Senior Lecturer in Resource Survey) – Tim's office in B53
15.15 – 15.45	Meet with Prof Mark Tibbett (Professor of Soil Ecology) – Mark's office in B37
15.45 – 16.00	Drink / Comfort Break
16.00 – 16.30	Meet with Prof Jane Rickson (Professor of Soil Erosion and Conservation) – Jane's office B37
<i>13th Sept</i>	
9.00 – 9.30	Meet with Dr. James Brighton (Head of Centre for Automotive Technology) – James' office in B61
10.30 -	Meet with Mr. Bob Walker (Senior Technical Officer) – LEC at Wilstead, and possibly visit the Silsoe farm

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Following discussions with Anne and Heidi, areas of potential collaboration included:

- Soil and water management/engineering, including soil mechanics and degradation processes. Anne and Heidi highlighted the need for collaboration in filling a research/ skills gap, following the retirement of key personnel in the US;
- Slope stabilisation and erosion control on engineered slopes (e.g. Highway cut and fill slopes);
- experimental methodologies related to land degradation e.g. rainfall simulation capability and capacity (and training in the design, build and use of equipment);
- Training of researchers on secondment, using travel exchange programmes as already set up with research organisations in Germany and Italy.;
- Off-road vehicle dynamics, including compaction, wheelings, remediation and laboratory simulations of trafficking;
- Material coatings and corrosion – Anne was given some literature including the contact details of academic/researchers in the Manufacturing department who work on material coating and corrosion;
- Exchange of researchers between the UK and US to work on projects of mutual interest.

3. DEFENCE ACADEMY, CRANFIELD UNIVERSITY (SHRIVENHAM)

3.1 Location

Cranfield University's site at Shrivenham, part of the Defence Academy of the United Kingdom, formerly known as the Defence College of Management and Technology, lies close to the M4 motorway which links London and South Wales. It is eight miles (12 km) from Swindon, the nearest town, which lies off the M4. The University campus is well positioned for communication with other major towns and cities, with Bath, Cheltenham, Bristol and Oxford all within an hour's drive and London less than two hours away.

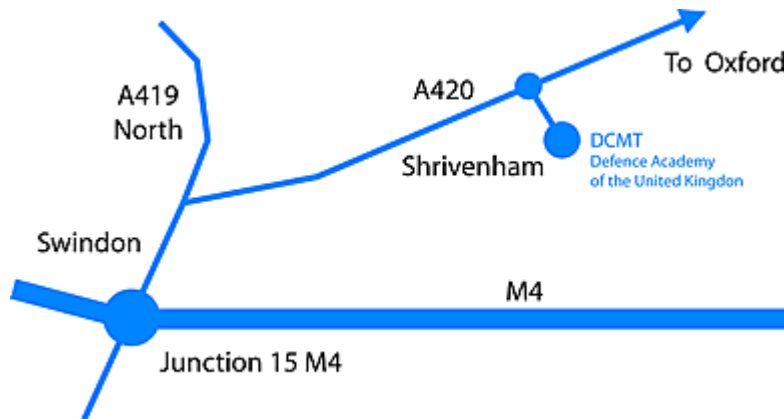


Figure 2 Shrivenham Campus in relation to the M4 Motorway

3.2 Capabilities

The Shrivenham site is home to Cranfield Defence and Security, one of five schools within the University, the other four being located on the Bedford site. Cranfield Defence and Security comprises three Departments; Engineering and Applied Science, Infomatics and Systems Engineering, and Management and Security.

The Department of Engineering and Applied Science is the focus for all activities associated with Weapons, Ordnance, Munitions and Explosives (WOME) at the University. It brings together expertise in a diverse, yet comprehensive, range of technologies to provide education, research and consultancy advice to the defence and security sectors. The University has some excellent facilities, many of which are unique. There are first class ballistic and explosive ranges on the Shrivenham site and a major ordnance test facility on Salisbury Plain – Cranfield Ordnance Test and Evaluation Centre (COTEC). In addition the University has facilities for synthesising, manufacturing and testing explosives and WOME devices.

Approximately forty members of the Department staff at Shrivenham, many of them renowned internationally for their work, are directly engaged on WOME-related activities. Over half of them hold doctorates. They conduct research, provide consultancy services to the UK MOD and to industry and teach UK and overseas students at postgraduate level. In support of these functions the university has the following capabilities:

3.2.1 Energetic Material Synthesis, Prototyping and Manufacture

Cranfield University's Centre for Defence Chemistry has facilities for the development of new energetic compositions. It provides a capability in synthesis, analysis and characterisation, together with formulating, small scale manufacturing, and testing and evaluation. The synthesis of energetic materials including explosive compounds and energetic polymers, take place in a well-equipped laboratory which provides for every stage of compound development. Compatibility studies can be carried out on new energetic compounds with a view to formulating explosive compositions (ie PBXs). The University can synthesise and deliver small amounts of highly pure explosive compounds for forensic studies and related work, in particular nitrate esters, nitramines, nitro-aromatics and organic peroxides. Cranfield has remote mixing and pressing facilities together with testing and evaluation equipment.

3.2.2 Physical Analysis

The University has the capability to undertake physical and mechanical characterisation of energetic materials. The University has several large active research groups in the field of physical and mechanical analysis of materials and has a track record in working with industry and MOD in characterising materials for munitions qualifications, in-service surveillance, accident investigation and supporting international collaborative programs.

3.2.3 Chemical Analysis

Cranfield can undertake chemical characterisation of propellants, high explosives, initiators, pyrotechnics and improvised explosives. The University has a dedicated group specialising in chemical analysis of explosives with extensive experience in in-service surveillance of WOME for industry, developing new international standards on behalf of MOD and exploiting/reverse engineering battlefield intelligence holdings for MOD.

3.2.4 Hazard Testing

Cranfield University has the capability to undertake the full spectrum of hazard tests on energetic materials in accordance with NATO standards, etc. At the Shrivenham site it has an accredited test house for the undertaking of small scale sensitiveness tests. At the Cranfield Ordnance Test and Evaluation Centre (COTEC) on the Salisbury Plain Training Area (SPTA), the University can conduct Fragment Impact, Bullet Impact, Fast Heat, Slow Heat, 12m drop, Sympathetic Reaction and Shaped-Charge Jet Impact tests in accordance with AOP-39.

3.2.5 Range Testing

Cranfield University holds a 22 year lease from MOD on the COTEC Test and Evaluation facility on the SPTA. This allows the University to test and characterise explosives and complete weapons. Capabilities present at COTEC include firing of

munitions and devices, including proof firing, with conditioning within the range of - 50° C to + 71°C, bullet and fragment attack tests, drop and spigot intrusion tests, static explosive trials, including fragmentation, countermeasure evaluation using a flare test track and a high altitude test facility, standard and mini liquid fuel fires tests, bonfire tests, also slow cook off trials, shaped charge jet and sympathetic reaction tests, firing of small arms and light anti-tank weapons in a totally enclosed range under controlled conditions and vertical firing /subsequent recovery of projectiles. In addition COTEC has WOME processing, transport and storage facilities. COTEC is accredited to ISO 9001.

3.2.6 Environmental Testing (Impact of the Munition on the Environment)

Cranfield University's Environmental Science Group has the capability and experience to conduct a variety of WOME environmental testing in sampling and collection of explosive residues in soil environments from fully and partially detonated ordnance, studying the degradation of explosives through natural weathering, use of soil columns to assess the fate and transport of explosives through the ground to underwater aquifers and monitoring emissions to air from the burning of waste explosives. Cranfield University has provided consultancy services to the MOD Defence Ordnance safety Group (DOSG) on the environmental effects of WOME including the organisation and running of demonstrator programmes to evaluate the effectiveness of environmental assessment techniques.

3.3 Academic Courses

Cranfield University delivers a range of courses at postgraduate level. It runs 30 MSc/PG Cert courses and over 200 short courses. Of those relating to explosives and environmental matters, it offers the following:

3.3.1 Environmental Awareness and Compliance in Defence

This course has been introduced to raise awareness of environmental issues, with a primary focus within the Defence sector and the acquisition process. The course aims to assist delegates with the skills, knowledge and development potential to understand and manage environmental problems at the practical level. Delegates are also introduced to aspects of environmental legislation and the mandatory requirements for formal compliance in Defence.

Course Duration: 2 days

Course content:

- Introduction to environmental awareness within defence acquisition;
- Defence-related activities influencing the quality of the environment;
- Effective methods of environmental protection in Defence acquisition;
- Introduction to environmental legislation;
- Environmental compliance in Defence;
- Defence-related case studies;
- Written exam.

3.3.2 Sustainable Development (SD) in Defence Acquisition

This course has been developed to assist with the MOD's commitment to deliver SD within Defence. In order to achieve SD policy, all MOD programmes, policies and

projects have to address the environmental, social and economic aspects of conducting business. This process also includes procurement being considered as an integral part of the acquisition cycle. This course has been developed to assist with the MOD's commitment to deliver SD within Defence.

Course Duration: 2 days

Course Content:

- Introduction to Sustainable Development;
- Sustainable Consumption and Production;
- Climate Change and Energy;
- Natural Resource Protection & Environmental Enhancement;
- Sustainable Communities;
- Policy Making and Standard Setting;
- Key Indicators;
- Tools Available;
- 1-1.5 hour written exam.

3.3.3 Environmental Management - Project Oriented Environmental Management Systems (POEMS)

Environmental Management within Defence Acquisition is a mandatory requirement as detailed in the Secretary of State (SoS) for Defence's Policy Statement. The nature of the equipment and services that the MoD procures is such that they are likely to have some environmental consequences associated with their operations. Therefore exercising effective control mechanisms in order to minimise and mitigate any environmental impacts requires careful management in the acquisition process. Project Oriented Environmental Management Systems (POEMS) has been developed and mandated for all defence acquisition projects in order to enable environmental impacts to be minimised through life of equipments and services. Previously POEMS was taught as a three day 'awareness' course, giving delegates an introduction to the implementation process and an understanding of the main environmental aspects and impacts associated with defence acquisition projects. Due to structural changes within the MoD there is now a growing need for internal expertise in this area. For this reason, the original POEMS course has now been extended to 5 days and has become part of a practitioner training 'programme'. The training programme consists of three unique components:

Course duration: Five days

Course Content:

Taught elements:

- POEMS requirements, structure and implementation process;
- Information regarding application of POEMS to Commercial and Military off the Shelf and User Requirement Documents;
- Introduction to influencing and communication skills, restricted materials, available assessment tools and POEMS Audit;

- Identifying the need for further environmental assessment in the context of POEM.

Assessment:

- Continuous assessment in the form of theoretical activities throughout the course;
- End of course written exam

On-the-job training:

- Completion of practical activities as part of a structured mentored programme.

3.3.4 Ordnance, Munitions and Explosives (OME) Safety (Awareness)

Course Duration: 2 days

Course Content:

The course addresses the following subjects from an MOD perspective:

- Health and safety at work;
- Health and safety organisation;
- An introduction to explosives;
- Hazards to and from OME;
- Competency levels within OME;
- Accidents involving OME;
- The storage of OME;
- The transportation of OME;
- General safety and security of OME - Live firing demonstration (where practical). The course is held at the Defence Academy; Shrivenham (may be held at the customer's location but is individually priced).

3.3.5 Ordnance, Munitions and Explosives Safety (Intermediate)

Course Duration: 8 days

Course Content:

This course is designed for those responsible for managing activities involving Ordnance, Munitions and Explosives (OME) in a Defence Environment. Its aim is to outline the areas of knowledge they need to be familiar with, in order to begin to discharge their duties with respect to OME. It provides an overview of both the nature and properties of OME, and the regulatory controls which are applied in Defence, to ensure that they do not present an intolerable risk to employees and the public. This course is designed to relate to the UK MOD competency framework for ordnance and explosives safety at practitioner level. The course deals first of all with basic explosives chemistry and properties and progresses through explosion effects to applications in ordnance systems. The latter part of the course is concerned with the arrangements in place to control the risk from explosives. Lectures are provided on relevant Health and Safety legislation in the UK and the associated regulations. MOD policy, standards and internal regulations, classification, storage, security and conveyance of explosives, range safety and accident reporting and investigation are covered. Classroom work is supported by small-scale explosives demonstrations, as well as a comprehensive explosives and pyrotechnic demonstration on the college

explosives range and demolition area. General explosives subjects are taught by the academic staff at Cranfield whilst specialist areas such as policy, legal security and range safety are undertaken by visiting lecturers from MOD and the Defence industry.

3.3.6 MSc in Explosives Ordnance Engineering

Course duration: 1 year full-time, up to 5 years part-time

Course content:

To qualify for the Explosives Ordnance Engineering MSc, students must successfully complete formal examinations, coursework and a research project. The course comprises two parts, Students take nine core modules covering the main disciplines and choose three elective modules based upon their particular background, future requirements or interests. The list of modules is as follows:

- Ammunition Systems 1 – Warheads;
- Ammunition Systems 2 - Delivery Systems;
- Ammunition Systems 3 - Target Effects;
- Future Developments; Scanning the Horizon in Explosives Ordnance Engineering (EOE)
- Insensitive Munitions (half module);
- Introduction to Explosives ;
- Manufacture and Materials Properties of Explosives;
- Gun Propellant;
- Research Methodology (half module);
- Testing and Evaluation of Explosives (half module);
- Transitions to Detonation (half module);
- Computer modelling tools in EOE (half module);
- Explosives for Nuclear Weapons;
- Explosives and the Environment (half module);
- Forensic Investigation of Explosives and Explosive Devices;
- Pyrotechnics;
- Risk Assessment for Explosives (half module);
- Rocket Motors and Propellants.

In the second part of the course students undertake a research project - a list of prospective projects is provided each year by the teaching staff. Alternatively, with the agreement of the teaching staff/supervisor, students may undertake appropriate research of their own choosing.

3.4 USACE visit details and agenda

The visit opened with a description by Mrs Temple and Dr Hooper of the UK MOD approach to environmental management of the effects of munitions on Test and Evaluation and Training rounds (Annex i academic papers). This covered the following topics:

- UK Ministry of Defence Land Holdings;
- The Project Oriented Environmental System (POEMS);
- Assessment of UK MOD Munitions;

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- MOD Training Ranges;
- Source/Pathway/Receptor model;
- Future Technical Work.

In addition to the above USACE were given an over view of Defence Chemistry and tour of laboratory facilities, met Explosive Research and Development Area staff to discuss facilities and tour of 100 metre range and a tour of the Defence Capability Centre.

4. ECOLOGY OF MILITARY LAND MANAGEMENT - CONTEXT, APPROACH, ECOSYSTEM DYNAMICS

4.1 Ecosystems

This section of the report was requested by the sponsor, it focuses on literature associated with the adaption and evolvement of ecosystems in specific soil environments in military training ranges. This chapter was written by Professor Jim Harris of School of Applied Sciences, Cranfield University.

Ecosystems in military training lands are no different, initially, than any other type of ecosystem under periodic stress and disturbance regimes. The nature of those disturbances make these systems analogous to intensive agriculture and land engineering environments such as strip mines and quarries. Therefore we might expect them to be as degraded. However there is evidence that active, as well as abandoned, military training areas are refugia for rare and endangered species (Warren and Buttner, 2007; Cizek et al, 2013). This has been attributed to military areas being very heterogeneous environments containing large undisturbed areas, highly disturbed areas, and gradations in between (Warren et al, 2007). Such heterogeneity is known to be a driver of system biodiversity and stability (Oliver et al, 2010). Also such sites are much less likely to be subject to intrusion by the general public, hunters or poachers. Considering that biological conservation is not a primary goal of such sites makes this outcome even more remarkable.

However there is evidence that without judicious management significant on site deterioration can occur which reduces ecosystem function, and in this context impact of safety and reduce training realism (Warren and Herl, 2005). Military vehicle training causes significant damage to landscapes, disrupting soil surfaces and damages and kills vegetation and soil biota (e.g. Prosser et al, 2000; Haugen et al 2003).

An emerging approach to overcome the difficulties faced with competing priorities for restoration focussed on individual species or other environmental outcome is the “ecosystem services” approach which provides a broad, structured understanding of the ecosystem goods and services derived from the natural capital of a system (Rey Beneyas et al, 2009, Montoya et al, 2012). Anderson et al (2005), in an editorial piece heading a Special Issue of the *Journal of Terramechanics*, have indicated that there are a number of significant research gaps which needed to be addressed in respect to military vehicle impacts, namely:

- Regionally incomplete vehicle impact assessments;
- Incomplete measures of site degradation;
- Meaningful indications of site degradation;
- Thresholds of catastrophic change;
- Spatial/temporal scale of impact regimes typical of military installations;
- Up-scaling and downscaling impact study results;
- Cumulative impacts (spatially and temporally);
- Interaction between vehicle impacts and other land use activities; and,

- Integrating vehicle impact study results into vehicle based impact models.

Although many lessons can be learned by comparison with general soil disturbance and restoration literature, the unique nature of military sites and the pressures on them make these gaps priorities for future work.

4.2 Soil Ecology of Military Environments

There is an extensive literature on the use of soil microbial indicators in restoration programmes, which have been demonstrated to provide unequivocal indication of restoration success (e.g. Harris, 2003; 2009), with clear links to ecosystem process and structure (e.g. Coleman 2008), and natural capital and ecosystem goods and services (Robinson et al, 2013), and are well suited and flexible in the context of policy development (Ritz et al, 2009). Accompanied by a suite of simple soil physico-chemical measurement, this provides a robust indicator of success of forest restoration which can be directly related across ecosystem types, regions and globally. The adverse impact of heavy training loads on soil properties have been investigated, with impacts including higher bulk density, decreased soil carbon and nitrogen (e.g., Garten et al, 2003).

The impacts of tracked vehicular disturbance can be severe, but there is evidence that certain biological characteristics can recover within a few years. For example, Althoff et al (2009) reported that although there were severe reductions in soil microbial biomass and nematode diversity and richness declined sharply on the passage of tracked vehicle traffic they returned to the same or higher levels during a four year study period – this was also true for the group most severely affected (79%) earthworms which are particularly susceptible to the impacts of mechanical disturbance. Peacock et al (2001) demonstrated losses to microbial biomass, as measured by phospholipid fatty acid analysis, in proportion to increases frequency and severity of vehicular trafficking. In the same study a recovery of microbial biomass ten years after replanting in a restoration scheme, but with a very high variance – in other words there were areas under the trees which had recovered fully, whereas those areas outside the zone of influence of these trees had made no progress. This points to the need for active intervention to secure ecosystem recovery, as such heavily impacted sites often demonstrate a hysteresis pattern, where recovery from disturbance is much slower than normal successional patterns. The efficacy of soil microbial community measurements to indicate restoration success after military disturbance has been demonstrated in many studies globally (e.g. Heitkamp et al, 2008).

There are also effects on the biogeochemistry of military sites. Silveira et al (2010) have demonstrated major effects of training loads on carbon cycling on military training sites, strongly correlated to intensity of training. Essentially respiration increased and soil carbon decreased, with potential longer time and wider impacts on the site and beyond. Houser et al (2005), for example, working at Fort Benning found impacts on streams lower in the catchment, with elevated ecosystem respiration rates – indicating export of nutrients from the training area. In a parallel study Bhat et al (2006) found extent of military areas negatively correlated with stream water total nitrogen and organic carbon. Further work by this group (Bhat et

al, 2007) reported changes in the hydrological regime also. Such effect on biogeochemistry has been demonstrated in several studies (e.g. Silveira, 2009).

4.3 Case Studies for Soil Management and Restoration in Disturbed Environmental Settings

Management of army training areas in a systematic way is relatively recent. An early study outlined by McDonagh et al (1979) which reports the effects of pressures on an Australian Army training site, which were suffering from erosion and waterlogging, making training over half the area untenable. Interventions included the establishment of deep rooted perennial pasture species and planting tree species.

There have been examples of successful interventions to restore ecological functions on military sites. Wilcox et al (2012) found that contour ripping was effective in reducing run-off in an experimental site at Fort Hood, Texas, more effective than compost manure applications. With heavily impacted soils replanting with trees often results in recovery of soil characteristics (e.g. Garten et al, 2003) although this of course renders the areas restored in this way unsuitable for tank training. However Maloney et al (2008), in a study of secondary succession of areas representing 55 years of natural reforestation indicated that although soil carbon and nitrogen stock had recovered in this time period, soil bulk density would take between 83 to 165 years, without active interventions.

Several approaches are emerging for the management of military lands, with a central focus on GIS resident systems for providing decision support in determining training schedules. The use of indices based on multiple ecological characteristics have been suggested and trialled (e.g. Althoff et al, 2007) and show great promise for scheduling training regimes and targeting restoration efforts. Even so, it must be noted that there is a pressing need for more research to further inform expert systems and expert systems (Singer et al, 2012). A number of approaches are also available at the DoD's own "Conserving Biodiversity on Military Lands" Website.

However, one problem that military training lands face is the need for repeated soil trafficking. Most work on restoration has focussed on sites after previous uses have ceased – i.e. mining (a transient use, in effect) and intensive agriculture – much of the literature on restoration of military training lands is focussed on post closure situations. There are a large number of research gaps in this area which need to be addressed – and this in the context of a comprehensive programme of investigation across multiple disciplines: soil science, ecology, hydrology at a catchment scale.

5. SALISBURY PLAIN TRAINING AREA

5.1 Location

Salisbury Plain Training Area (SPTA) is located in Wiltshire, 12 miles (19.2km) north of the city of Salisbury. The Army started land purchase on Salisbury Plain in 1897 and the total area of the current estate is just over 38,000 hectares. The Training Area measures 25 miles by 10 miles (40 km by 16 km) and occupies about one ninth of the county of Wiltshire.

Defence Training Estate Salisbury Plain (DTE SP) provides walkers with the opportunity to see an archaeological landscape, which is of unparalleled importance in Northern Europe. There are some 2,300 archaeological sites including features dating back to 4000 BC, along with more recent Roman settlements. Salisbury Plain has one of the most dense concentrations of ancient long and round barrows anywhere in Britain.

Salisbury Plain is the largest area of chalk grassland in north-west Europe and contains 40% of the remaining area of this habitat in the UK. In recognition of its importance about 20,000 hectares of grassland have been designated as a Site of Special Scientific Interest (SSSI) and Special Area Conservation (SAC).

Species supported within the grassland include butterflies now uncommon in Britain such as marsh fritillary, adonis blue and brown hairstreak. All have healthy populations in the area. SPTA is also designated as a Special Protection Area (SPA) for birds, such as the stone curlew where 10% of the UK population are found. Roe deer are numerous and are often seen by day.

5.2 Soil Characteristics

The Chalk Group, found extensively in NW Europe, was deposited in the Upper Cretaceous from about 100 million years to 65 million years ago. It is an extremely pure, very fine-grained limestone, being nearly pure calcium carbonate, and consists mainly of coccolith biomicrites formed from the skeletal remains of minute planktonic green algae (coccolithophores). The deposits may also contain larger microscopic fragments of foraminifera, ostracods and bivalves.

The Chalk Group is divided into three broad categories:

- Upper Chalk - softer than the Middle Chalk, this is a white, uniform massively bedded deposit, up to 400m in thickness, with nodular flint, often in regular layers or seams;
- Middle Chalk – is a white homogenous deposit with occasional marl deposits;
- Lower Chalk - relatively soft and greyish in colour with clay content increasing from top to bottom.

5.3 Capabilities

At over 94,000 acres (38,000 hectares) SPTA is the UK's largest training area, roughly 25 miles by 10 miles. About 25,400 acres (10,000 hectares) are permanently closed to the public for safety reasons – Larkhill and Westdown artillery impact areas, and Warminster live firing area. During the past 35 years, over 9 million large-calibre rounds have been fired on SPTA, and live firing takes place on an average of 340 days a year. SPTA offers live firing and other facilities for armoured vehicles, artillery, engineers, infantry and aircraft. The newest facility is the 'village' on Copehill Down used to train for operations in built-up areas. Regulars, Territorials and Cadets use the training area as a whole, as do our NATO allies. SPTA also manages the airspace over, and adjacent to, the Plain, in addition military aircraft from all three Services use this airspace both by day and night, sometimes being joined by NATO aircraft. Everything possible is done to minimise the effects of low flying over the area, although this is of course an unavoidable aspect of essential training for military operations. Every effort is made to minimise the impact from military training on people's lives: a special parish liaison system is in place offering a direct point of contact to the people in all of the 45 parishes around the Plain. A regular newsletter informs residents of forthcoming exercises and other planned military activities. Noise levels are constantly monitored, and exercise planning takes due account of the effects of training on the local population. The military garrisons around the Plain (Bulford, Larkhill, Tidworth and Warminster) contain some 14,000 soldiers. They, and visiting units, spend some 600,000 man days on the Plain annually.

5.4 USACE Visit Details and Agenda

DTE Salisbury Plain 18 Sept 2012	Host: Richard Snow, MSc, PG Cert, HND, DTE Sustainable Development DE Operations, Land Warfare Centre, Warminster, Wiltshire BA12 0DJ Telephone: 01985 848773 Mobile: 07500882 823
09.45	Arrive Westdown Camp, Building 21 met by Richard Snow
10.00- 10.30	Military Brief 10-10.30 by Lt Col (Retd) Nigel Linge
10.30- 11.00	Move to Building 21, Meeting Room Brief from US Army Corps of Engineers (Study Objectives and US Estate management updates)
11.00- 11.30	DTE Overview of Training Estate Management (Environmental Management Systems, Noise, Environmental effects of Ordnance Munitions and Explosives, Sustainability and Environmental Assessment, Rural Infrastructure and Delivery, Forestry Initiatives, Estate Management Contracts) (Richard Snow and Nigel Hayward)
11.30- 12.00	Natural Environment Brief by Dr Stuart Otway
12-12.30	Historic Environment Brief Chris Daniell
12.30 - 13.00	Discussion and exchange of information
13.00- 15.00	Tour of SPTA (Packed lunch provided)

6. OTTERBURN TRAINING AREA

6.1 Location

The Otterburn Training Area (OTA) comprises 23,085 hectares of land located between the A6096 trunk road and the Scottish Border. The land is centred at NGR NT 851 055 and lies within the curtilage of the Northumberland National Park.

6.2 History

6.2.1 Prehistoric

Information detailed within the Otterburn Training Area Integrated Land Management Plan (OTA ILMP) and the Northumberland National Park website indicates the range land to have a history of human use that extends to Neolithic times (circa 2200BC). Analysis of ancient pollen indicates that fire was used to create clearings on the land for the grazing of cattle at that time.

6.2.2 Agriculture

The first evidence of arable farming in the region occurs in the Bronze Age (circa 1500BC) and this use continues with increasing intensity until the reforms of agricultural practices and Enclosure Acts in the period 1600 to 1850. The region then assimilates elements of the “planned landscapes” present in southern England, with the consolidation of farms, improvement and enclosure of former waste land, introduction of sheep farming, clearance of woodland, and the construction of cattle enclosures and drove roads. Further diversification occurred when prices of sheep and wool fell, resulting in grouse shooting increasingly competing with agriculture from the mid-19th century onwards, also the introduction of forestry plantations and the use of the land for military training. Exploitation of the area for minerals and the production of milk and milk products, which occurred extensively elsewhere in the region, was largely precluded from the locality by the absence of rail transport.

6.2.3 Military

Military activity is recorded as having occurred alongside agriculture since the Roman occupation of the UK (circa 54BC to 410AD) and continues to the present day, with Roman Roads and military camps being recorded along with evidence of the protracted conflicts between England and Scotland.

The use of the land for training of a mechanised “industrial army” commences in the early 20th century with the purchase of the extreme northern extent of the range by the “War Office” of that time, circa 1911, for use as an artillery range. Subsequently, further parcels of land have been purchased in order to accommodate changes to the types and performance of weapons systems, tactics and training requirements, the most recent acquisition of land taking place in 1987.

Only minimal infrastructure is required for the land to operate as a range. However the military infrastructure has gradually developed during the 95 years that the range has been in use, to cater for each generation of weapons and training, detailed briefly below:

- Provision of access roads and hard standings as light gun firing points (gun spurs) – dates unknown;
- 1940s – antitank firing areas using moving target rail systems and static armoured vehicle hulks;
- Date unknown – provision of mortar firing points;
- 1980s - development of small arms Battle Shooting Areas (BSAs) with electric “pop up” target ranges;
- 1980s – provision of heavy gun spurs for the now redundant, 155mm Field Howitzer 70 (FH70) artillery system;
- 2003 – upgrading of the peripheral access road system and heavy gun spurs for the use of the 45 tonne 155mm Artillery System 90 (AS90) self-propelled gun and the Multiple Launch Rocket System (MLRS).

Considering the long history of the site, it is likely the majority of conventional weapons systems used by the Army throughout the twentieth century will have been fired within the OTA.

6.2.4 Site Description and Current Site Use

The OTA is comprised of rolling, open moor land with steeper more rounded hills present in its northern area. The land has a distinctly open aspect and features an absence of development, with the exception of occasional agricultural buildings, minor military infrastructure and conifer plantations.

The land varies in elevation from approximately 240m to 450m above Ordnance Datum (aOD). The high ground acts as a watershed between the River Coquet and the River Rede, which lie to the north east and south west respectively. Numerous surface watercourses rise on the land and in general these flow either eastwards towards the River Coquet or southwards towards the River Rede.

Alongside military training, the land is utilised primarily for sheep farming (cows are also sporadically grazed during the summer months) pursuant to Agricultural Holdings Act tenancy agreements, with 31 tenanted farms present within the training area, containing forty nine agricultural dwellings and approximately 120 residents. Areas of the land are regularly open for controlled access to the general public, for recreational purposes.

The OTA is primarily configured as an artillery range and it would be possible to safely fire any of the conventional weapons currently used by the British Army at the training area, with the exception of ground to air missiles and the Multi Launch Rocket System (MLRS) using fully operational rockets. These munitions are precluded as the training area is too small to safely accommodate the firing templates of these systems.

Main Battle Tanks (MBT) are currently also precluded due to the very soft ground conditions found at the ranges, however there is evidence that the Chieftain MBT system was historically operated at the site.

6.3 Ordnance Munitions and Explosives Used at OTA

Live firing that takes place at OTA usually consists of UK weapons systems, such as:

Principal UK weapons systems;

- 105mm calibre towed light gun;
- 155mm calibre Self Propelled Gun, Artillery System 90 (AS90) and the former Field Howitzer 70 system (FH70);
- Multi Launch Rocket System (MLRS) – reduced range practice rocket only (RRPR);
- 51mm and 81mm calibre mortars;
- Small arms, currently predominantly 5.56 mm calibre, but previous systems including 9mm and 7.62mm calibres amongst others.

6.4 Environmental Overview

6.4.1 Geology & Hydrogeology

British Geological Survey of England and Wales sheet number 5 'The Cheviots' and sheet number 8 'Elsdon', show the land comprising the Otterburn Ranges is underlain by a variety of geological materials, the north area being characterised by igneous rocks and the south by sedimentary strata.

6.4.1.2 OTA North Region

The part of the range lying to the north of Alwinton and the Ridlees Burn is underlain by volcanic rocks of Lower Devonian age, mainly comprised of heavily weathered andesite material.

Andesite is a fine-grained crystalline volcanic rock, often of grey colour, normally occurring as an extrusive or surface deposit. They are currently considered to be comprised of a mixture of older igneous deposits taken into solution by fresh lava, prior to eruption.

The presence of this heavily weathered igneous rock results in the pronounced steep, but well-rounded hills that characterise the igneous landform, with the potential for a discontinuous layer of peat to be present on the high tops. The land has been subject to glacial action and a strata of boulder clay is present within many of the valley bottoms.

Due to the presence of the low permeability igneous material, the Environment Agency Groundwater Vulnerability of West Northumberland (sheet 1) classifies the area as a non-aquifer (little or no groundwater). This land is drained by surface watercourses with the localised presence of alluvial strata associated with the River Coquet on the eastern boundary of the ranges, being recorded as a minor aquifer.

6.4.1.3 OTA South Region

The land to the south of Alwinton and the Ridlees Burn is underlain by younger sedimentary rocks of Lower Carboniferous age. The groundmass is comprised of a

variety of sandstone and limestone strata, including some “coal measures” elements. The landform is comprised of rolling uplands incised by the numerous river valleys.

Due to the greater permeability of these units, the southern area is predominantly classed as a minor aquifer. However the “Fell Sandstone Group” that occurs in a broad belt of east west orientation across the centre of the training area (with a further element along the eastern boundary), is classified as a major aquifer. Hence in the southern area, significant surface and groundwater receptors are both present.

6.4.2 Groundwater Abstractions and Source Protection Zones

The MoD Defence Estates, Estates Information Portal (GEODE) indicates that 5 boreholes are present within the range complex.

The Environment Agency website does not record any potable water supply Source Protection Zones within the locality of the Otterburn Range.

6.4.3 Hydrology

The high ground forming the range complex forms the watershed between the River Coquet to the north and east of the land, and the River Rede, which lies to the south west. Numerous surface watercourses, some ephemeral, rise on the land and in general these flow either eastwards towards the River Coquet or southwards towards the River Rede.

6.4.4 Conservation Designations

The OTA is located within the boundary of the Northumberland National Park.

OTA location indicates that the bulk of the site of interest does not fall within any area protected by a further conservation designation. However 12 Sites of Special Scientific Interest (SSSI) protected under the Wildlife and Countryside 1981 are located within the curtilage of the OTA.

6.5 USACE visit details and agenda

Otterburn 19 Sept 2012	Host: Major Peter Ackroyd RA, Range Safety and Liaison Officer Otterburn, Newcastle upon Tyne, NE19 1NX Civilian Telephone: 0191 239 4201
09.30	Meet at Otterburn HQ Building
9.45 -10.15	Brief from US Army Corps of Engineers (Study Objectives and US Estate management updates and innovations)
10.15 – 12.30	Discussion, exchange of information and site tour
12.30	Depart

7. CRANFIELD UNIVERSITY ENVIRONMENTAL / EXPLOSIVE RESEARCH

Cranfield University at Shrivenham is carrying out a number of research activities in support of its work for the UK Ministry of Defence to understand the fate and transport of the products of munitions used on its training ranges

As part of essential training regimes significant quantities of ordnance munitions and explosives are used by UK military forces and it is believed that continuous firing may cause cumulative environmental impacts. Therefore, UK military training areas such as Salisbury Plain Training Area (SPTA) require best environmental practice to minimise these potential effects. In order to do this it is essential that contaminants that are released into the environment are recognised and understood. Conventional explosives such as TNT and RDX are reasonably well understood in terms of their use and composition and to some extent how they behave in the environment. It is the new Insensitive Explosives, namely Polymer Bonded Explosives (PBX) that are entering into service which are less understood in terms of their potential toxicity and behaviour in the environment.

It is for these reasons that practical trial experimental work has been undertaken on PBX to understand the fate and transport effects of PBX in the soil environment. Experiments to date have involved detonating full and partial samples of PBX so that residues can be collected and analysed to quantify any remaining compositions in the soil environment. Further to these experiments chalk soil columns have been constructed by re-packing chalk that is representative of SPTA and have been placed in controlled laboratory conditions. Various preliminary studies have been undertaken on the columns to ensure reproducible and representative results can be achieved and these have included hydrologic conductivity, absorption and porosity tests.

The results of the preliminary tests have proved that the re-packed columns are suitably representative for laboratory purposes. The next stage of the soil column study will involve artificially spiking the chalk columns with known contaminants, such as high explosives and PBX compositions so that transport mechanisms can be analysed and the environmental fate can be fully understood. It is expected that the columns will be analysed on a weekly basis by collection of any leachate. Following a 12 month monitoring period the columns will be cut into sections so that a full investigation of the contaminants can be analysed.

Secondly Cranfield University has developed a small scale test to assess, on an accelerated time basis, the migration of contaminants through soil into aquifers - produce outline proposals for further work.

A small percentage of ordnance (estimated to be less than 2%), does not function properly, resulting in unexploded ordnance (UXO). The UXO's often have to remain in the training ranges, potentially creating un-safe conditions. In addition to the safety issues the UXO that remains in the range can either be cracked or split, which can lead to the leaching of the high explosive into the environment and in particular into groundwater. This leaching can lead to high levels of contamination in isolated areas

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or has the potential to cumulatively affect larger areas. As mentioned above, conventional explosives are reasonably understood in terms of their chemical compositions although, new generation explosives, such as are PBX less so.

In response to this experiments to determine the breakdown of PBX in the environment over time have begun. These experiments involve exposing a PBX that has a composition of 88% RDX and 5% Hydroxyl-Terminated Polybutadiene (HTPB) based binder and 7% plasticizer to the open environment. To fully assess this type of PBX it is essential to monitor it in different weather conditions and in different forms for at least 12 months. The PBX will remain in the open environment, and will be in the following forms:

- Pristine HTPB – a control sample;
- Pristine PBX – newly manufactured;
- Cut open PBX – exposing the RDX crystals;
- Partially detonated PBX – unburnt.

The PBX samples are being monitored at equal intervals to determine any observational and breakdown products by mass balance, photography and chemical analysis.

8. UK MOD COLLABORATION WITH CRANFIELD UNIVERSITY

Cranfield University at Shrivenham have an excellent relationship with the UK MoD and this is through various research activities undertaken on their behalf and teaching courses to personnel. Much of the research and courses within Defence Chemistry are associated with 'explosives in the environment', the effects and impacts that they can cause. This expertise has led to Cranfield staff being invited to Chair and sit on specific explosives and environmental related committees, for example, the Joint Technical Requirements Committee's subcommittee (JTRC SC) on the environmental effects of Ordnance, Munitions and Explosives. The purpose of the UK MOD JTRC SC is to draw together Subject Matter Experts (SME) to define what programmes of work should be carried out both in Government and Industry in order to ensure that the use of OME by the Armed Forces for Training and by MOD and its contractors for Trials, Test and Evaluation is in accordance with national and international legislation and that it represents best environmental practice. Membership of the JTRC SC comprises representatives of various departments within MOD and its Agencies, academia and environmental consultancy firms providing services to MOD as follows:

8.1 MOD Departments

- Defence Equipment and Support/ Defence Ordnance Safety Group – MOD Abbey Wood, Bristol (approval for use of OME and advice to MOD project teams on OME-specific environmental policy. It is the sponsor of the JTRC SC);
- Safety, Sustainable Development and Continuity Division – MOD Main Building, London (custody of central MOD environmental policy);
- Defence Equipment and Support/ Defence General Munitions Project Team – MOD Abbey Wood, Bristol (acquisition of the majority of OME required by MOD);
- Defence Equipment and Support Environmental Science Group – MOD Ensleigh, Bath (conduct of environmental surveys of current and former MOD ranges);
- Defence Science and Technology Laboratory – MOD Porton Down (conduct of research that MOD does not wish to contract out to industry, also for all MOD international collaboration);
- Defence Infrastructure Organisation/formerly Defence Estates – Sutton Coldfield (MOD estates policy);
- Defence Infrastructure Organisation/formerly Defence Training Estates – Warminster (responsible for the training estate upon which the Armed Forces conduct operational training);

8.2 Academia

- Cranfield University at Shrivenham – Defence Academy of the United Kingdom (responsible for teaching and research on general and OME-related environmental matters, also for NATO collaboration on behalf of the Defence Ordnance Safety Group and the Defence Science and Technology Laboratory).

8.3 Environmental Consultancy Firms

- QinetiQ Ltd (research and consultancy services for MOD);
- SKM Enviro Ltd;
- Worley Parsons Ltd) (consultancy services for MOD);
- Frazer Nash Ltd.

8.4 Companies

- QinetiQ plc. – Fort Halstead, Sevenoaks and other sites (responsible for the management and running of MOD Test and Evaluation ranges, also for research for MOD into the environmental effects of OME)

8.5 Scientific/Technical

It is recognised that whereas the outputs from OME are well understood, the fate and transport of the products of functioning of OME is less so. The JTRC SC therefore is addressing the question:

- What scientific/technical work should be undertaken in the short/medium term in order to ensure the longer term environmental viability of the MOD training ranges (this is described in the “Shrivenham” section of this report).

8.6 Managerial

Over recent years MOD has undergone extensive changes, not the least being the formation of the Defence Infrastructure Organisation, drawing together various former MOD departments into a coherent whole responsible for all MOD land and buildings. At the same time Defence Equipment and Support/ Defence Ordnance Safety Group is focussing upon its core advisory role in support of the acquisition of OME. As sponsor of the JTRC SC and its associated programmes, it wishes to rationalise which parts of MOD is responsible for the various environment related issues appertaining to the use of OME on the ranges. It is therefore addressing the following questions.

- 1 Who should in future sponsor this work and arrange the provision of the necessary resources?
- 2 What transfer of responsibility and resource should take place, and when.

9. INTERNATIONAL COLLABORATION

9.1 Cranfield University and NATO Collaboration

As sponsor of the JTRC SC, Defence Equipment and Support/ Defence Ordnance Safety Group tasks Cranfield University at Shrivenham with the provision of independent technical support on NATO, USA/Canada/UK trilateral and other collaborative programmes on the environmental effects of OME. This includes attendance at, and participation in, NATO Applied Vehicle Technology Panel (AVT) and Strategic Environmental Research and Development (SERDP) meeting programmes. This forms part of the overall international collaboration programme coordinated by the Defence Science and Technology Laboratory (DSTL). Details of this work are covered further in this section of the report.

9.2 NATO Applied Vehicle Technology Panel (AVT)

The NATO Applied Vehicle Technology Panel has been established as it strives to improve the performance, affordability, and safety of vehicles through advancement of appropriate technologies. The Panel addresses vehicle platforms, propulsion and power systems operating in all environments (land, sea, air, and space), for both new and ageing systems.

To accomplish this mission the members of the AVT community exploit their joint expertise in the fields of:

- Mechanical systems, structures and materials ;
- Propulsion and power systems ;
- Performance, stability and control, fluid physics.

Within these categories there is a need to manage the environmental impacts of OME. Therefore, a specific AVT panel group titled Munitions Related Contamination – source characterisation, fate and transport has been set up. The objectives of this group are to:

- Share results and conclusions from research carried out within the participating countries;
- Transfer expertise and technology to a wider range of nations;
- Develop technical guidance for environmentally responsible management of military ranges;
- Summarize the work in a technical guidance document;
- Perform a field demonstration following the technical guidance document in one of the participating countries.

On-going and future studies will be coordinated if desired by the participants. The work conducted will be limited to the environmental impacts related to past and present use of munitions. Furthermore, it will be highly beneficial for the nations who are starting programs in this area to join and learn from other countries as well as share their experiences and problems. This will result in a more comprehensive final report.

9.2.1 Topics Covered

The most important topics of discussion will be the characterisation of sites, the impacts of live-fire training on the environment, and the dissemination of the results of on-going research. The work conducted will be limited to environmental impacts of past and present use of munitions. This includes the following subjects:

- Source of contamination;
- Source term evaluation;
- Fate and transport evaluation;
- Solutions to munition related contamination.

9.2.2 Deliverables and/or end Product:

Deliverables:

- Presentation of on-going research at scheduled meetings;
- Annotated bibliography with abstracts and keywords of relevant reports;
- Translation of selected non-English-language reports;
- Demonstration and short course with cooperative fieldwork;
- Optional: Overview of current remediation techniques.

9.2.3 End Product:

Technical guidance document on environmentally sustainable management of firing ranges

To date there has been various outputs from members in terms of discussion and knowledge sharing, mainly based on best practice on military installations, these include:

- Soil sampling strategies – this has focused heavily on multi-increment sampling. Members attended a multi-increment course, which was run by Mr Chuck Ramsey from Envirostat.org, Colorado, USA;
- Soil sample preparation and specifically analytical Methods;
- Fate and Transport (part 1) of explosives through soil, lab studies, dissolution and transformation;
- Fate and Transport (Part II), field studies, hydrogeology, including sampling methods for surface and groundwater;
- Toxicity and exposure assessment.

Other discussions have focused on specific techniques to prevent contamination at military installations, such as:

- Collection of Explosive Residues: Physical Changes of Comp B residue in a salt marsh impacts area (USA);
- Testing of Insensitive Munitions 60-mm High Explosive Rounds (USA);
- Biodegradation of 2,4,6 Trinitrotoluene (Turkey);
- Contaminants on Shooting Ranges (Switzerland);

- Sustainable Ranges: Environmental Aspects of Energetic Materials R&D Programme (Canada);
- Heavy Metal Transport from a Firing Range (Norway).

9.3 NATO Symposium

In addition the NATO Applied Vehicle Technology Panel (AVT) held a Symposium under the auspices of AVT 177 –“Munition and Propellant Disposal and its Impact on the Environment” was held in Edinburgh between 17 and 20 October 2011. Three papers were prepared for this conference. The first was for the Keynote Speaker Alan Nicholl (Director Weapons) “Munition and Propellant Disposal and its Impact on the Environment”. This keynote address covered the following topics:

- National overviews of current environmental issues, policies and emerging legislation - what are the drivers for sound environmental management?
- Range vulnerability, hazards and risks - assessment of levels of contamination what damage are we doing to our infrastructure?
- Techniques for mitigating the effects of environmental contamination and remediating range damage - what are we doing to repair that damage?
- Development of energetic materials and munitions with reduced environmental impact - what are we doing to develop less toxic munitions
- General and bespoke munition demilitarisation techniques - what tools do we currently have at our disposal for demilitarisation?
- Novel demilitarisation and remediation techniques - what new tools are on the horizon?

The second paper “Managing the Environmental Effects of Munitions – the UK MOD Approach” gave the UK national overview of management of the environmental effects of Ordnance, Munitions and Explosives. The paper covered the following topics:

- UK legislative and MoD policy drivers – current and emerging UK law and the MOD Secretary of State’s implementation of that law
- The MoD’s Project Oriented Environmental Management System (POEMS) - how it works and is it fit for purpose?
- The Defence Estate on which training takes place – the Salisbury Plain Training Area
- The planned way forward – a conceptual model for forward prediction of environmental consequences

The third paper “Managing the Environmental Effects of Insensitive Munitions Compositions: Air, Land and Water”. This paper described academic research projects that are currently being undertaken at Cranfield University to determine the levels of environmental impact during the use of IM in operational and training activities. The following topics are described in the paper:

- The viability of measuring and capturing air pollutants during open burning to determine the environmental effects of burning IM compositions.

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- The migration of explosive contaminants through soil matrices - exposing PBX contaminated soil to specific environmental conditions including ultraviolet light and differing levels of rainfall.

Copies of these three papers have been supplied to the contract sponsor, along with a Technical Evaluator's Report on the conference, giving a critique of all the papers presented.

Other international collaboration work has included participation in the following committees:

- Vehicle Technology meetings (AVT), 177, 179 and 197;
- Vehicle Technology meetings AVT 177 Symposium, Edinburgh, Scotland
- The Strategic Environmental Research and Development (SERDP) meeting, Washington, D.C, USA

The work carried out under the auspices of these meetings is reported in a paper "International Collaboration - Provision of Independent Technical Support on the Environmental Effects of Ordnance, Munitions and Explosives" by Tracey Temple. A copy of this paper has been supplied to the contract sponsor. Also supplied are three Annexes:

- Life Cycle Assessment – Portuguese
- AVT 197 Agenda – April 2012
- Generic munitions Description"

Papers can be accessed in Annex i, ii, iii

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